# CED WORKING PAPER





EFFECT OF RATION ENERGY DENSITY
ON CATTLE PERFORMANCE

Ray F. Brokken
D. A. Dinius

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COMMODITY
ECONOMICS DIVISION

ECONOMIC RESEARCH SERVICE U.S. DEPARTMENT OF AGRICULTURE

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dry matter intake functions, $Y_i = f_i(X_2)$, and the corresponding energy intake functions, $X_2 \cdot Y_i = X_2 \cdot f_i(X_2)$. Set I is linear in DM intake and quadratic in energy intake and Set II is hyperbolic in DM intake and linear in energy intake:

| Set I | Set II |
|---|---|
| (1a) $Y_i = A_i + B_i X_2$ | (2a) $Y_i = A_i'/X_2 + B_i'$ |
| (1b) $XY_i = A_i X_2 + B_i X_2^2$ | (2b) $XY_i = A_i' + B_i' X_2$ |
| $(A_i > 0,\ B_i < 0)$ | $(A_i' > 0,\ B_i' >,=,\text{or}<0)$ |

Function (1b) has a maximum at $X_2 = -A_i/2B_i$. With respect to increasing values of X, function (2b) is increasing if $B_i' > 0$, invariant if $B_i' = 0$ or decreasing if $B_i' > 0$.

Second, consider these two sets of functions for each of two animals, $i = 0,1$, one of which eats much more and gains much more than the other regardless of which ration energy density they both receive; $Y_1 > Y_o$ and $g_1 > g_o$.

The potential importance of these two considerations is evident in Figure 1. Charts A and B of Figure 1 show the relationship of dry matter intake per unit metabolic weight for two animals for the linear and hyperbolic functions with parallel functions in Chart A, and converging functions in Chart B. Corresponding energy intake functions are shown in Charts C and D.

The relevant range of values on energy density may be such that there is little difference between the functions of Set I and Set II over this range. Both the elevation and the rate of decline in the functions (1a) and (2a) is very important in whether the corresponding energy intake curves, (1b) and (2b), are increasing, more or less flat or decreasing over this relevant range.

The importance of whether the dry matter intake curves for the faster and slower gaining animals are parallel or converging is illustrated in the corresponding energy intake curves of Charts C and D.

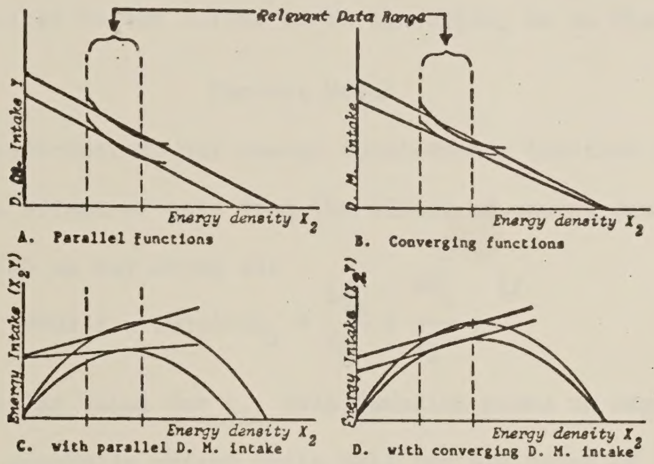


Figure 1. Voluntary daily dry matter intake and corresponding energy intake functions for two animals of different gain potential.

When dry matter intake curves are parallel, Chart A, the corresponding energy intake curves, Chart C, are diverging. For the case illustrated the faster gaining animal is affected more than the slower gaining animal by changes in ration energy density. However, if the DM intake curves become steeper the maximum point of function (1b) shifts leftward and the slope of function (2b), $B_i'$, may become zero or negative. A similar effect occurs from a set of lower curves, for example from a sample of low gaining animals: The maximum point on function (1b) would shift downward and to the left while function (2b) would shift downward and its slope, $B_i'$, would become zero or negative. For a pair of very steep parallel DM curves, corresponding energy intake curves decline over the relevant data range. Then as energy density increases, the absolute change in energy intake is negative and the greater for the slower gaining animals.

If there is little or no difference between animals of different performance rates in the absolute change of energy intake owing to a change in ration energy density as in Chart D, then we would expect their corresponding dry matter intake curves to be converging as in Chart B.

General Model

The Lofgreen-Garrett net energy requirements function is used for separating the effect of gain from the effect of energy density on feed intake [3] which we may write as:

(3) $Y_i = .080892 - .031487X_2 + \frac{bg_i}{X_2} + \frac{cg_i^2}{X_2}$ . 1/

Given a particular value for $g_i$, this function seems to explain feed intake per unit metabolic weight quite well for any value of $X_2$. 2/

Assign i = 0 for an arbitrary animal; i = 1,2,...,n for all others. What is the difference $Y_i - Y_o$?

From equations (1a) and (2a), $(Y_i-Y_o) = f_i(X_2) - f_o(X_2)$, which can be equated with the difference from equation (3), $(Y_i-Y_o) = \frac{b}{X_2}(g_i-g_o) + \frac{c}{X_2}(g_i^2-g_o^2)$, then solving for the general model $f_i(X_2)$:

(4) $Y_i = f_i(X_2) = f_o(X_2) + \frac{b}{X_2}(g_i-g_o) + \frac{c}{X_2}(g_i^2-g_o^2)$.

Hence, if the maintenance per unit $W^{.75}$ is the same, the difference between animals in daily voluntary feed intake per unit metabolic weight is owing to their difference in gain.

A function $g_i = g(X_2)$ is derived by equating (1a) or (2a) with (3):

(5) $g_i = \frac{-b}{2c} + \left[\left(\frac{b}{2c}\right)^2 - \frac{\left(-X_2f_i(X_2) - .031847X_2^2 + .080892X_2\right)}{c}\right]^{1/2}$

Hence, $g_i$ is a function of $X_2$ and the parameters in $f_i(X_2)$. When $X_2 \cdot f_i(X_2)$ in (5) is quadratic as in equation (1b), $g_i$ is a maximum at

$X_2 = (-A_i + .080892)/2(B_i + .031847)$.

## The Experiment

Five rations were formulated to vary in digestible energy (DE), the levels of which were determined in metabolism stalls to be 3.605, 3.390, 3.176, 2.951 and 2.804 Mcal/Kg on a 100% DM basis. Corresponding $NE_g$ ($X_2$ values) derived by NRC formulas [3] are: 1.280, 1.161, 1.032, 0.884, 0.778. Four pens of 2 animals each were used for each of the five rations.

## Results

For estimation purposes we replace $g_o$ with $\bar{g}_k$ in equation (4) for each of the k = 1,...,5, treatments. The models become:

$$(6) \quad Y_i = f_o(X_2) + \frac{b(g_i - \bar{g}_k)}{X_{2k}} + \frac{c(g_i^2 - \bar{g}_k^2)}{X_{2k}} + \varepsilon_i$$

which we estimated as

$$(6a) \quad Z_i = f_o(X_2) + \varepsilon_i \text{ where}$$

$$Z_i = Y_i - .05272 \frac{(g_i - \bar{g}_k)}{X_{2k}} - .00684 \frac{(g_i^2 - \bar{g}_k^2)}{X_{2k}} \quad \text{(See Footnote 2.)}$$

Alternatively,

$$(7) \quad Y_i = f_{o(X_2)} + \beta \frac{(g_i - \bar{g}_k)}{X_{2k}} + \varepsilon_i$$

For reasons too involved to discuss under the space constraints of this paper the results are superior for the alternative model, equation (7)

There is no difference in the statistical attributes of the two algebraic forms for $f_o(X_2)$. Both are plotted in Figure 2 but to save space only the linear functions are presented in Table 2.

Table 2. Regression Results, $Y_i = A_o + B_o X_2 + c(g_i - \bar{g}_k)/X_2$ a/

| Pens | $A_o$ | $B_o$ | c | $R^2$ |
|---|---|---|---|---|
| 10 high gain | .1773** | -.06248** | .02623 | .70660 |
| All 20 | .16935** | -.06204** | .05036** | .70552 |
| 10 low gain | .16145** | -.06165* | .01262 | .55036 |

a/ Y is in Kg., $X_2$ in Mcal/Kg and g in Kg/day

** Significant at 1% level  * Significant at 5% level

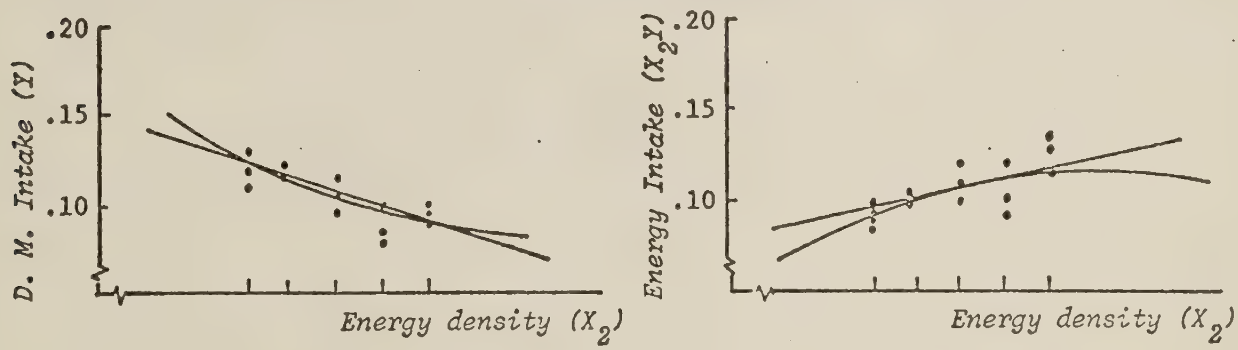


Figure 2. Experimental Observation and Regression Lines

We are also unable to choose between parallel and converging DM intake functions. The functions for the ten top gaining and 10 low gaining pens are almost exactly parallel but statistically do not preclude the possibility of diverging or converging functions. (The hyperbolic functions were slightly divergent.)

Table 3 shows how gain would be affected by changing energy density for each of two animals of different genetic capability under the energy intake functions of Set I function (1b), $g_o$ and $g_1$ and of Set II function (2b), $g_o'$ and $g_1'$.

The calculations shown assume that the dry matter intake function of the faster gaining animal is parallel to the slower gaining animal. The

absolute response in gain to a change in energy density is larger for the faster than for the slower gaining animal. Further, the response at the higher energy densities is greater under the linear energy intake function than under the quadratic energy intake function. In practical terms this means that substitution of low energy feeds for high energy feeds may not be economical even though price ratios have changed in favor of the lower energy ingredients. The suggestion is that such a change in rations would be even less wise in either the case of (a) the linear energy intake function or (b) the faster gaining animal.

Table 3. Effect of Energy Density (Mcal/Kg) on Gain (lb/day) for Fast Gaining and Slower Gaining Animals Under Quadratic and Linear DM Intake Functions. a/

| $X_2$ | $g_o$ | $g_1$ | $g_o'$ | $g_1'$ |
|---|---|---|---|---|
| 1.0 | 2.16 | 3.28 | 2.09 | 3.28 |
| 1.1 | 2.25 | 3.48 | 2.18 | 3.48 |
| 1.2 | 2.31 | 3.64 | 2.42 | 3.70 |
| 1.3 | 2.36 | 3.77 | 2.45 | 3.92 |

a/ The following functions for $X_2f_i(X_2)$ were used: for $g_o$, $X_2Y_o = .16935X_2 -.062037X_2^2$; for $g_1$, $X_2Y_1 = .20503X_2 - .062037X_2^2$ for $g_o'$ $X_2Y_0 = .0625 + .042787X_2$; and for $g_1'$, $X_2Y_1 = .0625 + .08049X_2$

## Summary and Conclusions

In contrast to previous studies, we have shown that energy intake and gain are increasing functions of ration energy density. However, the precise nature of the functions (a) as to whether the dry matter energy intake function is linear or hyperbolic in energy density and (b) whether differences in dry matter intake functions for animals of different genetic capabilities tend to be parallel or convergent remain to be established. These subtleties are interesting and appear to be important. Of course, more work is needed.

## Footnotes

1/ Since both $NE_m(X_3)$ and $NE_g(X_2)$ are a function of metabolizable energy (ME), [3] we express $X_3$ as $f(X_2)$: Log F = 2.2577 - .2213ME; $X_3$ = 77/F, F = $77/X_3$; $X_2 = 2.54 - .0314F \therefore X_3 = -2.4178/(X_2 - 2.54)$. Then $.077/X_3 = .077(-.4136X_2 + 1.05054) = -.031847X_2 + .080892$.

2/ The parameters for energy in Mcal per day per unit $W^{.75}$ are: for steers, b = .05272 and c = .00684; for heifers, b = .05603 and c = .01265. This difference is energy parameters between heifers and steers is owing to the difference in energy content of an additional unit of gain for animals that weigh the same. Obviously, there would be some variation in body composition in terms of energy per lb. of gain within these two classifications. Another set of coefficients is probably needed for bulls and perhaps additional sets for large breeds of heifers, steers and bulls.

## References

[1] Dinius, D.A., and B.R. Baumgardt, Regulation of Food Intake in Ruminants. 6. Influence of Caloric Density of Pelleted Rations. J. Dairy Science 53:311-316, 1969.

[2] Montgomery, M.S. and B.R. Baumgardt, Regulations of Food Intake in Ruminants. 2. Rations Varying In Energy Concentration and Physical Form, J. Dairy Science 48:1623-1628, December 1965.

[3] National Academy of Sciences-National Research Council, Nutrient Requirements of Domestic Animals; No. 4: Nutrient Requirements of Beef Cattle, 4th Rev. ed. NAS-NRC, 1970.